



NASA G7-GIBN Project



Trans-Pacific Astronomy Experiment Project Status

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Remote Astronomy over Trans-Pacific ATM Satellites

Trans-Pacific Astronomy Experiment

- Phase 2 of the *Trans-Pacific High Data Rate Satcom Experiments* following the Trans-Pacific High Definition Video Experiment
- A part of the Global Information Infrastructure-Global Interoperability for Broadband Networks Project (GII-GIBN)
 - Emerging global information infrastructure involving broadband satellites and terrestrial networks
 - Access to information by anyone, anywhere, at any time
 - Collaboration of government, industry, and academic organizations
- Demonstrate the use of broadband satellite links in a global information infrastructure with emphasis on astronomical observations, collaborative discussions and distance learning

(cont.)

Remote Astronomy over Trans-Pacific ATM Satellites

- **Interactive control of Mt. Wilson Observatory's 24" telescope**
- **Distribution of Mt. Wilson Images through the use of distributed file access technology – people, organizations, and equipment are becoming more distributed in nature**
 - Replication sites in Japan and the U.S.
 - Images from telescopes are stored in a distributed file system
 - Permits post-processing of images by other participants
 - Storage of Hubble Space Telescope archival images
- **Environment for collaborative discussions and learning**
 - A form of academic exchange between Japan and U.S. students

(cont.)

Remote Astronomy over Trans-Pacific ATM Satellites

- **Internet Protocol (IP)-centric applications**
 - IP-based applications are readily available to the general public
 - Involvement of schools and network researchers
 - Migration of research results to user applications
- **An opportunity to study issues of scale and interoperability**
 - IPv4 over ATM
 - IP Multicast (voice, video, and application data)
 - Distributed file access
- **Application to other projects**
 - e.g., NASA Solar System Internet/Mars Infrastructure effort

Remote Astronomy over Trans-Pacific ATM Satellites

Participation

- **Global Interoperability for Broadband Networks Project, G7-GII**
- **Current participants (astronomy experiment):**
 - AT&T
 - NASA GRC, GSFC, JPL, NREN
 - The George Washington University
 - University of Maryland
 - The Mt. Wilson Institute, in association with
 - Crossroads (CA), T. Jefferson (VA) High Schools
 - Soka High School (Japan)
 - Misato Observatory
 - Japan Ministry of Posts and Telecommunications
 - Communications Research Laboratory
 - Kokusai Denshin Denwa Co., Ltd.
 - Nippon Telegraph and Telephone
 - Intelsat/Comsat

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Potential Applications:

- **Global Network of Astronomical Telescopes**
- **Global Oscillation Network Group**
- **University of North Carolina, Tennessee State University**
- **Astronomy community and the general public**
- **Satellite communications community**
- **Network and distributed systems protocol researchers**
- **NASA Science and Engineering Information Infrastructure**
- **NASA Collaborative Engineering Environment**
- **FAA FICS-21 (FAA Integrated Communications System for the 21th century)**
- **NASA Solar System Internet Initiative/Mars Infrastructure**

Remote Astronomy over Trans-Pacific ATM Satellites

Interactive Observations

- Automated 24" telescope connected to a local telescope server
- Use of dedicated software for control and image capture
- Observations during day-time hours from Japan
- Use of distributed file access to propagate the images over satcom link

Remote Astronomy over Trans-Pacific ATM Satellites

IP-based Multicast

- Collaborative discussions during demonstrations
- Advantages: logical naming and efficient use of bandwidth for large, dynamic groups
- Virtual network - Casner: Multicast Backbone (MBone)
- Possible linkage with terrestrial MBone infrastructure
- Lecture mode vs. interactive mode over satcom links
- Layered encoding application

Remote Astronomy over Trans-Pacific ATM Satellites

Distributed File Access

- Effective means of sharing data
- Permits users to collaborate
- Access and location transparency
- Small local disk and shared file name space
- Server replication
- Facilitate transfers over satcom links
- Andrew File System (AFS) and/or High Performance Storage System (HPSS)

Remote Astronomy over Trans-Pacific ATM Satellites

Virtual InterNetwork Testbed (VINT)

- Based on NS originally developed at LBNL
- NS - a discrete event simulator targeted at networking research. It provides substantial support for simulation of TCP, routing, and multicast protocols
- NAM - Network Animator
- Empirical error model provides simulation results for comparison
- Facilitates academic participation
- Helps examine the issues of scale and heterogeneity in the evolving global information infrastructure
- High bandwidth satellite links with terrestrial connections

Remote Astronomy over Trans-Pacific ATM Satellites

Status

- NASA Research and Education Network:
 - JPL-to-NASA GSFC established
 - PVC assigned: (0,55)
 - NTTCP ATM level verification
- Mt. Wilson Telescope
 - Via PacBell Internet
 - Internet version of software on 14" test telescope
 - Migration to 24" telescope
- Laboratory testbed at JPL
 - Mbone applications and measurement tools (mtrace)
 - AFS server and clients
 - Trans-Pacific Experiment cell created
 - Cell name: TPae.jpl.nasa.gov
 - Server name: afstpa01.jpl.nasa.gov
 - IP address: 137.79.116.64

Remote Astronomy over Trans-Pacific ATM Satellites Network Test Plan

Status (cont.)

- Laboratory testbed at JPL (cont.)
 - PC-based Mbone application clients and AFS clients
(presently requires protocol converter -- workstation)
 - Windows 98 needs light client (beta) or protocol converter
 - Testbed has two virtual subnets
 - Mbone tunnel
 - Satellite delay simulator
 - Andrew Benchmark to be compiled and installed
- Multistate error model for Lawrence Berkeley National Laboratory
- Empirical satellite channel model using the multistate error model

Remote Astronomy over Trans-Pacific ATM Satellites Network Test Plan

Status (cont.)

•The Andrew Benchmark

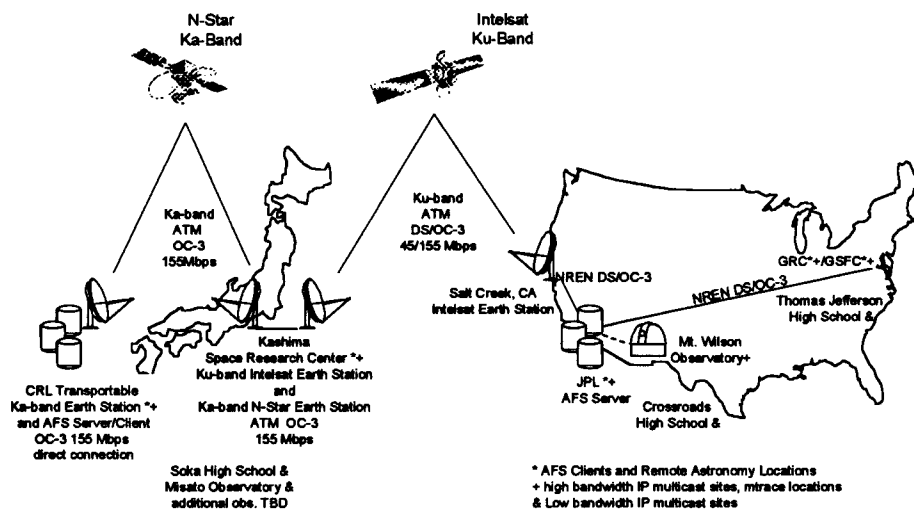
- **MakeDir:** Construct a target subtree that is identical to the source subtree
- **Copy:** Copy every file from the source subtree to the target subtree
- **ScanDir:** Traverse the target subtree and examine the status of every file in it
- **ReadAll:** Scan every byte of every file in the target subtree
- **Make:** Complete and link all files in the target subtree

• Multicast-based measurement tool: *mtrace*

mtrace reports the route from a multicast source to a receiver, along with other information about that path such as per-hop loss and delay statistics. Topology discovery through *mtrace* is performed as part of the tracer tool.

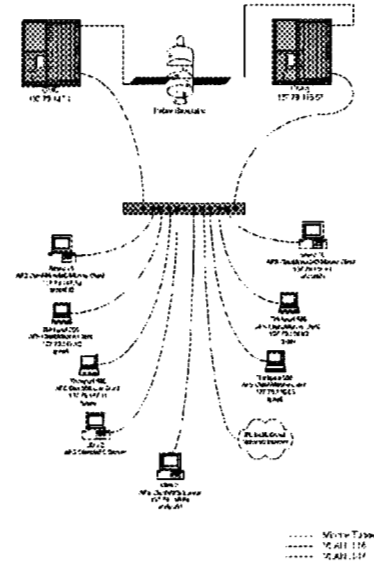
- Host
- Loss
- Delay

Trans-Pacific Connections



Remote Astronomy over Trans-Pacific ATM Satellites Laboratory Testbed

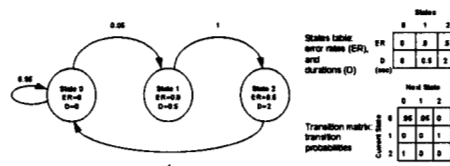
- Established a laboratory testbed for multicast and distributed file systems applications for the Trans-Pacific Astronomy Experiment. The testbed permits the storage of archived astronomical images and the verification of system operations between JPL and NASA Ames, GRC, GSFC, and participants in Japan.
- It will later be re-configured as an operational platform for conducting remote astronomical observations, collaborative discussions, and distributed systems studies.



Remote Astronomy over Trans-Pacific ATM Satellites Multi-state Error Model

- Deliver in report form the source code for a multi-state error model for the Lawrence Berkeley National Laboratory's (LBNL) Network Simulator.

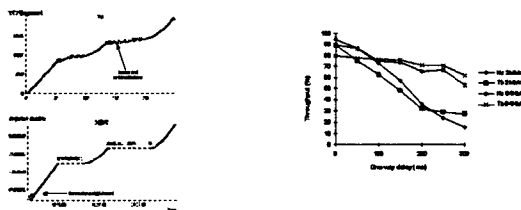
Multi-state error model permits the construction of detailed empirical or statistical channel models describing various conditions that affect a satellite link. The capability helps protocol researchers model detailed profiles of satellite channels and study their use in the global information infrastructure.



Remote Astronomy over Trans-Pacific ATM Satellites Empirical Link Model for Network Simulator

- Deliver in report form an empirical satellite channel model for the LBNL Network Simulator using propagation data from NASA Advanced Communications Technology Satellite.

The simulator, augmented with channel models, would permit the extensive study of scale and protocol interaction in current and future network protocols, including congestion control, reliable multicast, multicast routing, dynamic topologies, and integrated services.



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Sample Sessions

• The Structure of Galaxies

Observe examples of the various types of galaxies with the TIE telescope. Compare with HST observations of similar galaxies, both nearby and very distant. May also compare with Digitized Sky Survey observations of many galaxies

• The Lives of the Stars

Observe a number of nebulae with the TIE telescope. Include HII regions (stellar birthplaces), planetary nebulae (death sites of low-mass stars), and supernova remnants (death sites of high-mass stars). Compare with HST observations of similar targets, both in our Galaxy and in others (e.g., the Magellanic Clouds). May also compare with Digitized Sky Survey observations of many nebulae.

• Where are all the Stars?

Observe a number of Galactic star clusters with the TIE telescope. Use these observations, and archival ones from HST, to account for the ~100 billion stars in the Milky Way. Also observe a smaller number of spiral galaxies with the TIE telescope to aid in understanding the larger picture.

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Sample Sessions (cont.)

- Mt. Wilson images stored on local AFS server
 - AFS server performs synchronization to replicate the file at all locations
- Discussion using IP-Multicast tools
- Post processing of images using distributed file access system possible
 - Compositing of images
- Hubble Space Telescope archived images
 - Determined based on finalized schedule for trans-Pacific connections
 - More generic images will be pre-loaded
- Estimated 2-hour lectures

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Demonstration

- June-Sep 1999
- Mt. Wilson Institute, local schools (US and Japan), other GIBN participants
- Broadband satellite links with terrestrial connections
- Facilitates academic and public participation
 - Applications available on personal computers
 - Opportunities for research

Trans-Pacific Astronomy Expt..

Trans-Pacific Astronomy Experiment

Network Testing

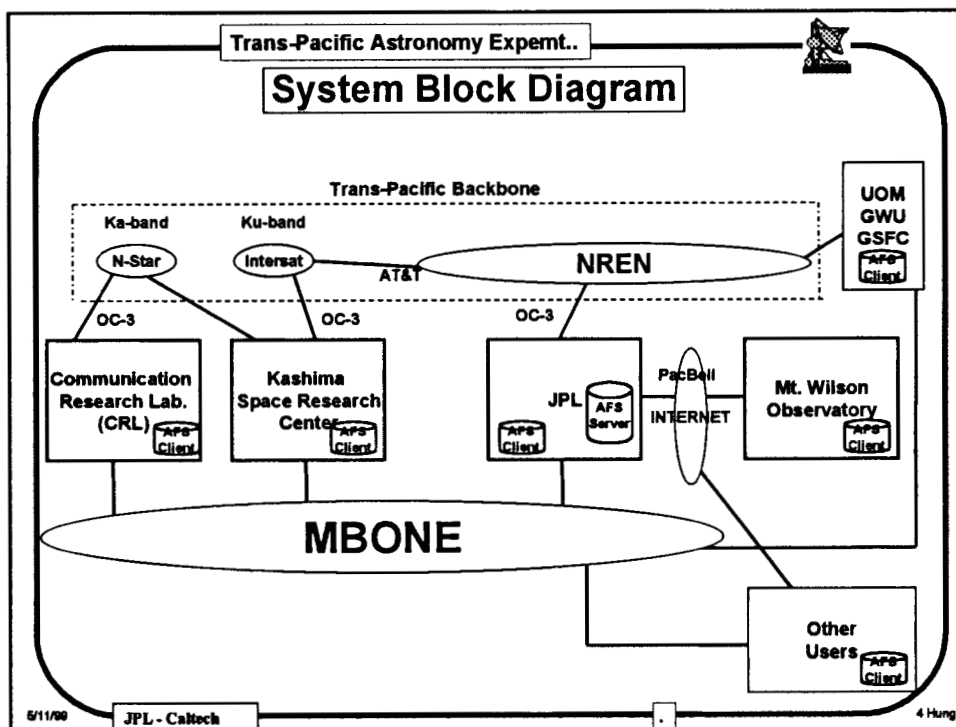
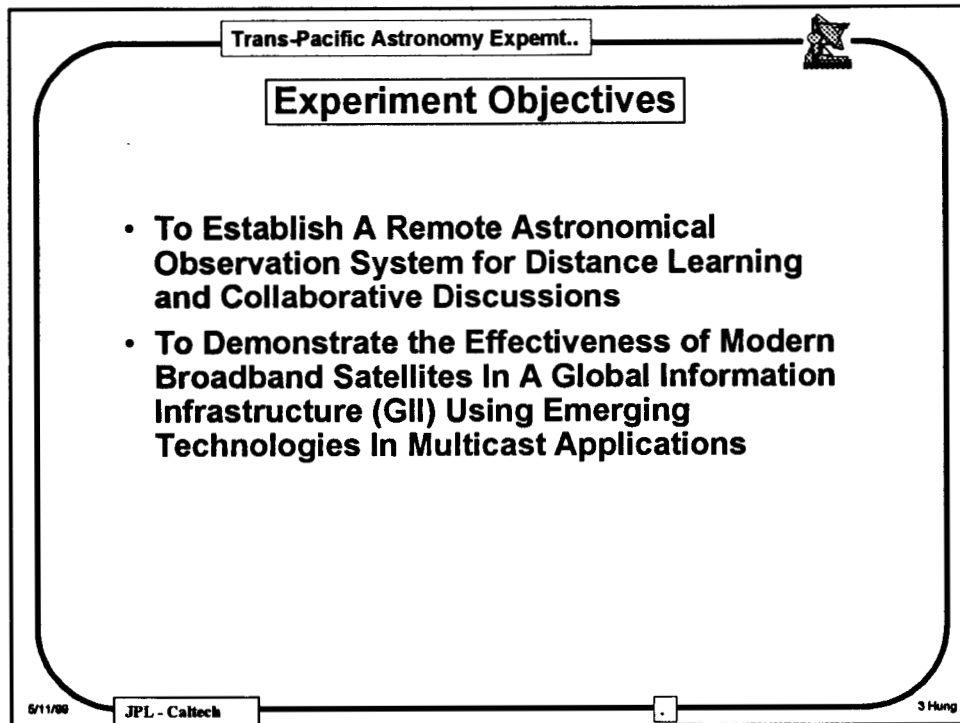
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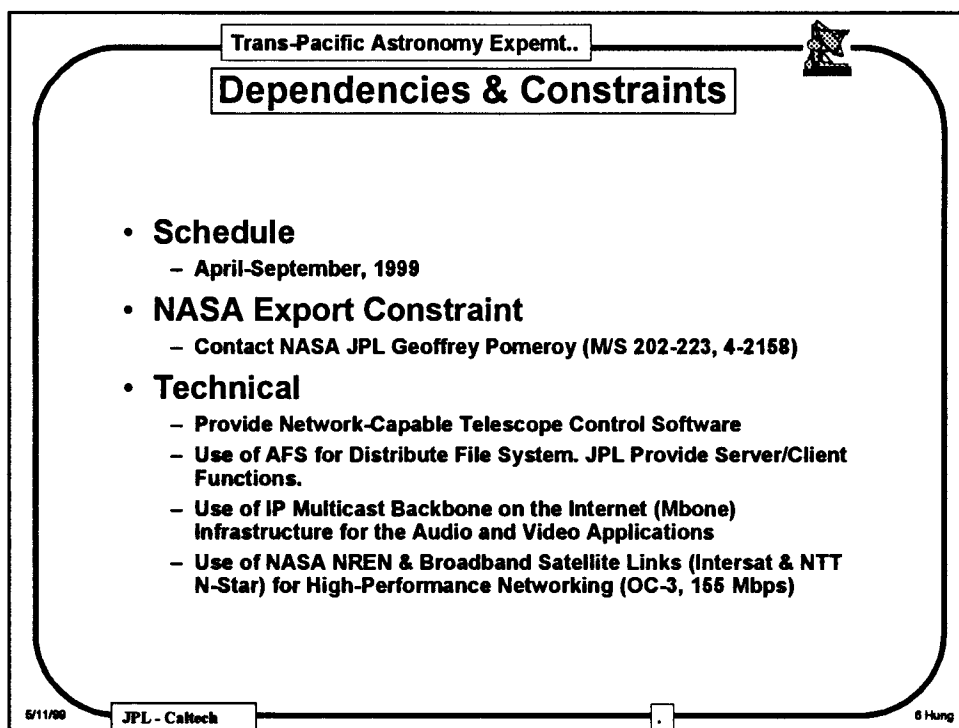
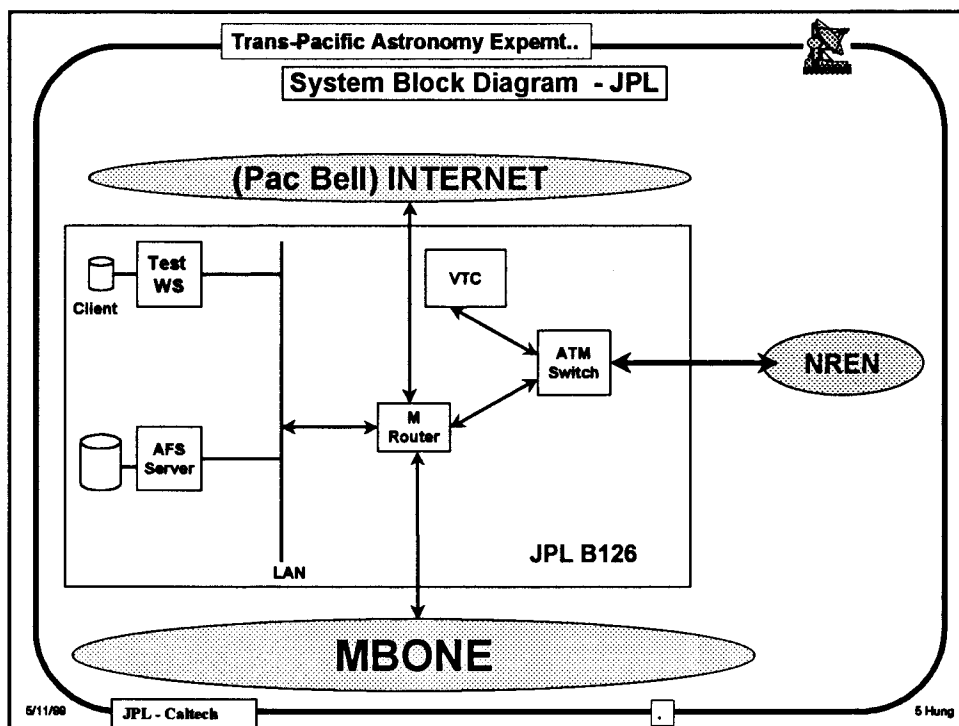
Trans-Pacific Astronomy Expt..

Trans-Pacific Astronomy Experiment

- Experiment Objectives
- System Block Diagram
- Dependencies & Constraints
- Requirements Summary for JPL
- Test Approach

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Trans-Pacific Astronomy Expt..

Dependencies & Constraints H/W & S/W List for Japan

- **Hardware**
 - AFS Server/Client Processor
 - M Router (VPN Capable)
 - PC for MBONE Application
- **Software**
 - Telescope Control Software
 - AFS Server/Client Software
 - M Router Software
 - VPN Software
 - Mtrace - Multicast-Based Measurement Tool
 - Software Monitor for IP Multicast & File System Protocol

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Trans-Pacific Astronomy Expt..

Requirements Summary for JPL

- Receive Mt Wilson Telescope Astronomical Observations Data
 - Via Pacbell Internet
 - Will Reliably Receive and Capture All Data From Instrument at Available Bandwidth
- Provide Telescope Control Data to Mt Wilson
 - Real-Time or Near Real-Time Support
 - Via Trans-Pacific Backbone and Pacbell Internet
 - Will Be Able to Transmit Control Data From Japan or Any Pis Areas Via JPL
- Provide Data Processing and Storing (Imaging) Data at AFS Servers
 - Master Data Resides at Servers
 - Near Real-Time Processing
 - Permit Post-Processing by Users

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Requirements Summary for JPL

- Provide (Imaged) Data to Astronomical User'S Group
 - Provide "Release" Replication and "Scheduled" Replication Data to Client Sites (Japan, GSFC, JPL,...)
 - Using NREN, NTON and High Data Rate Satcom (OC-3, 155Mbps) to Users
 - User'S Can Retrieval of Selected Images Data From AFS Client
- Provide Capabilities for Collaborates Discussion and Learning to Users
 - By MBone
 - VPN
- Provide Monitoring Capability At JPL
 - MBone
 - AFS

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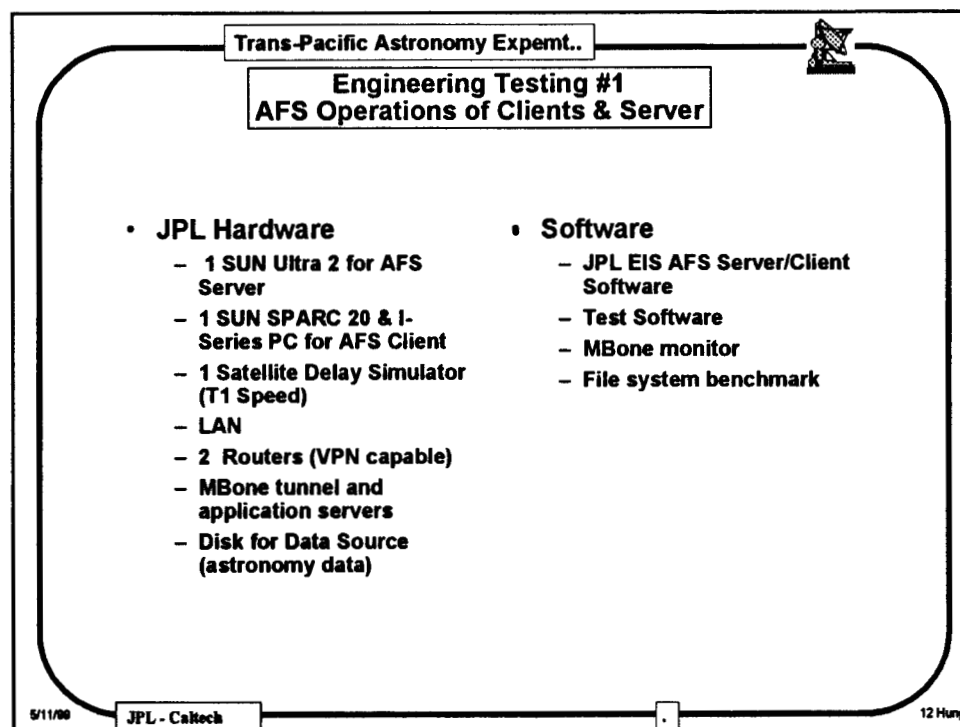
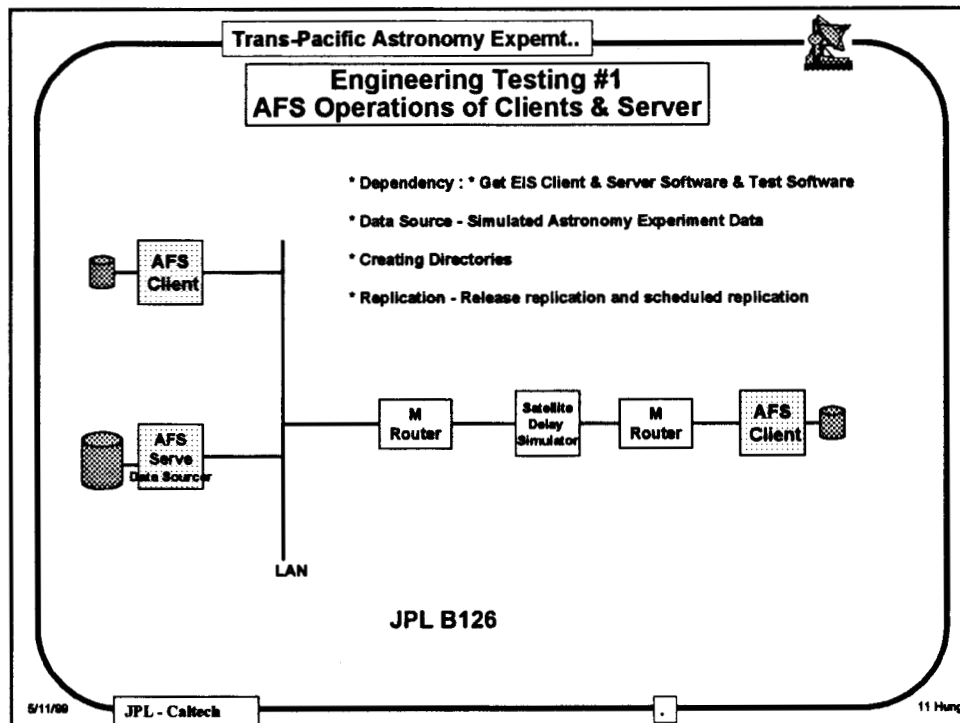
Test Approach

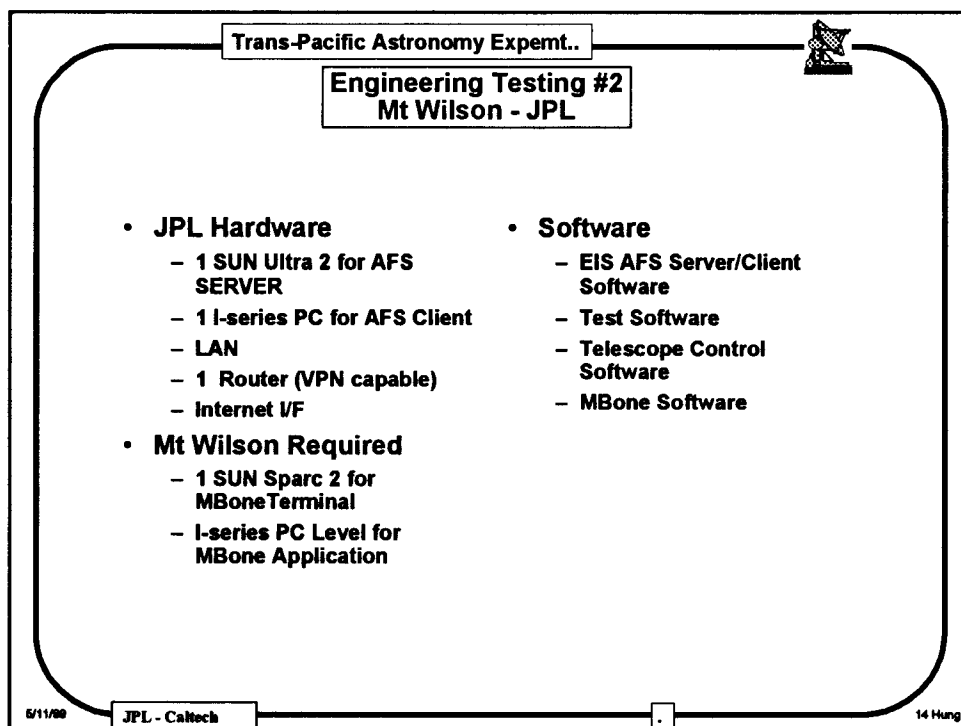
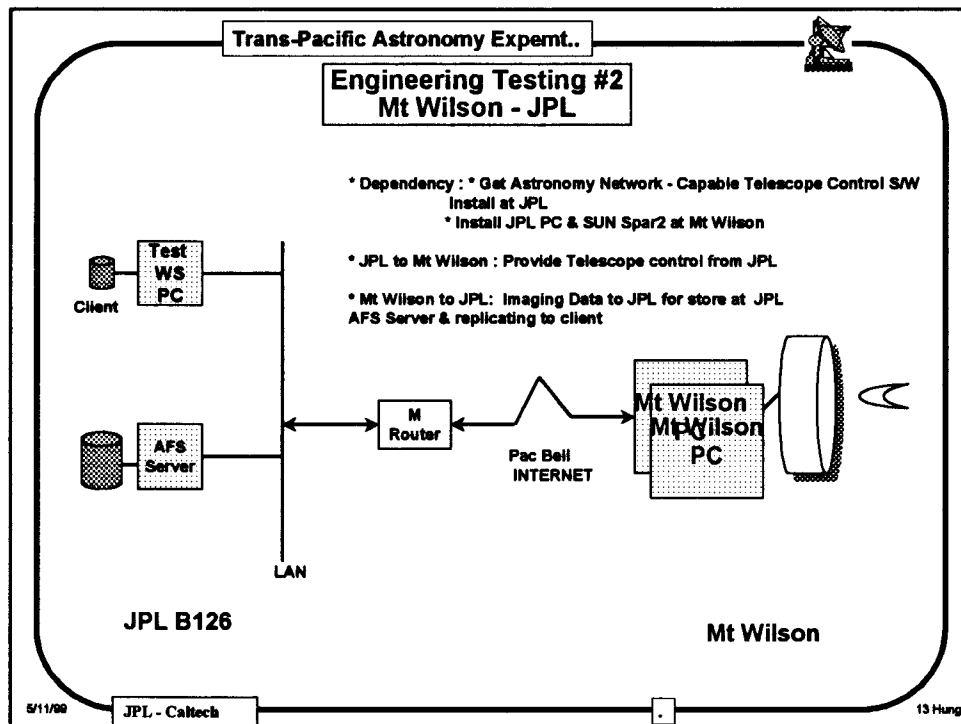
- 1. AFS Operations on LAN of Client and Server Machines Proved (JPL B126)
- 2. Mt Wilson - JPL Via PacBell Communication (Duplex) Proved
- 3. Japan- USA (Back Bone) Communication Proved. AFS Operations on LAN and WAN of Client and Server Machines Proved (JPL, Japan,...)
- 4. MBONE Operations on Remote Sites (Japan, JPL, GWU)

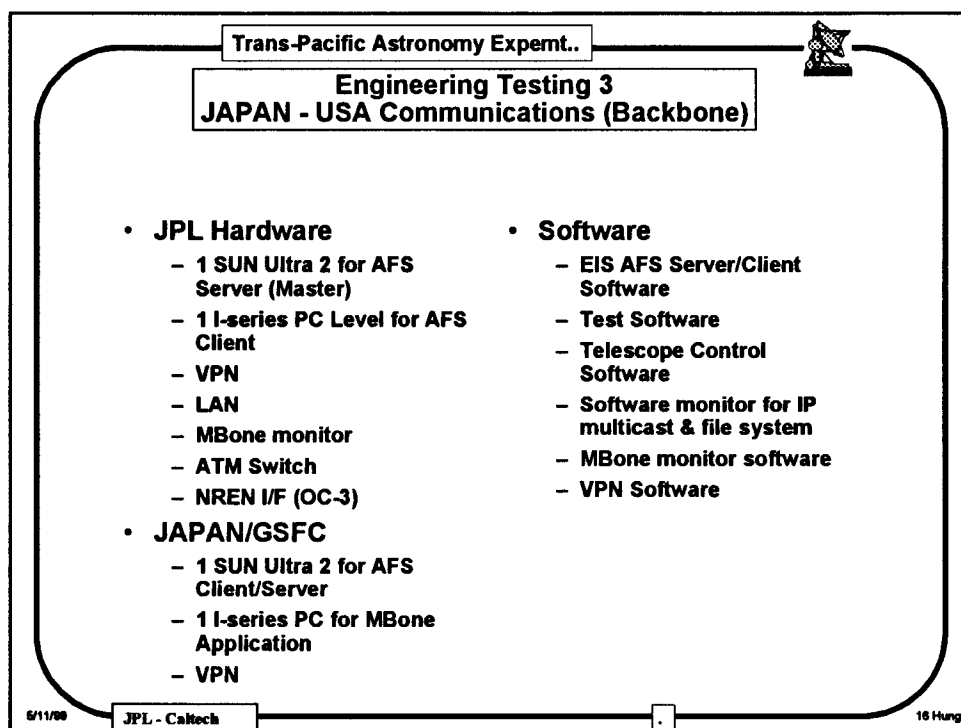
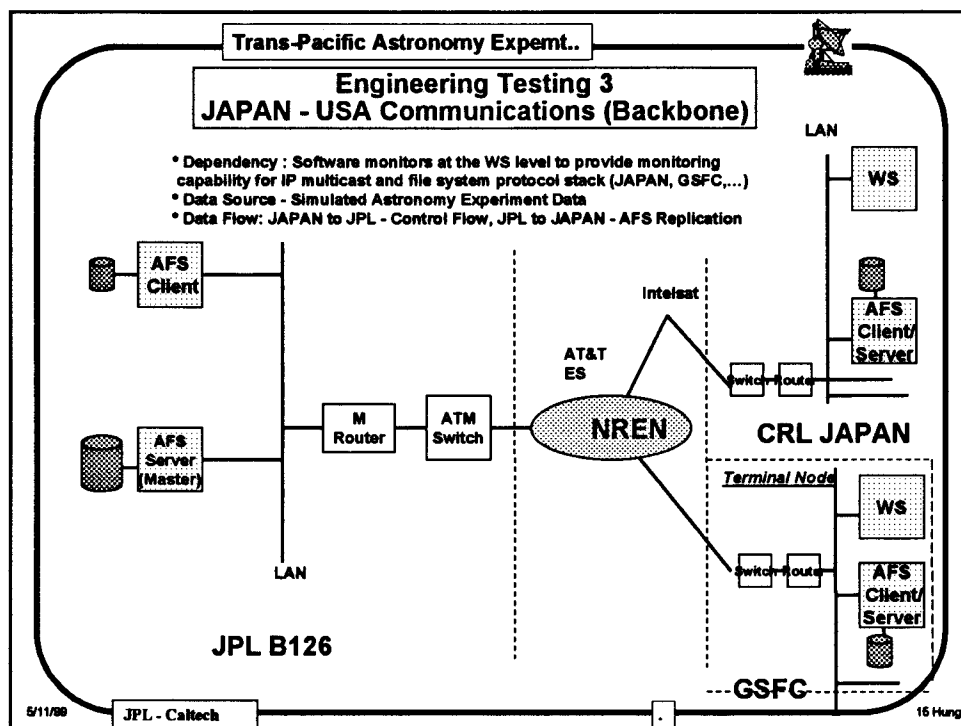
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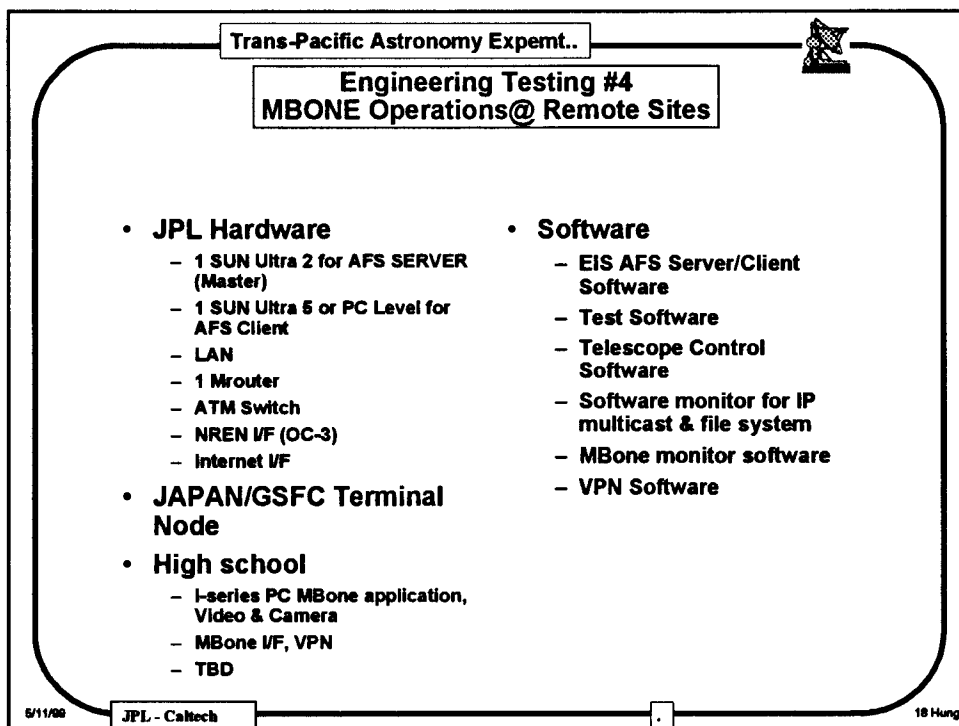
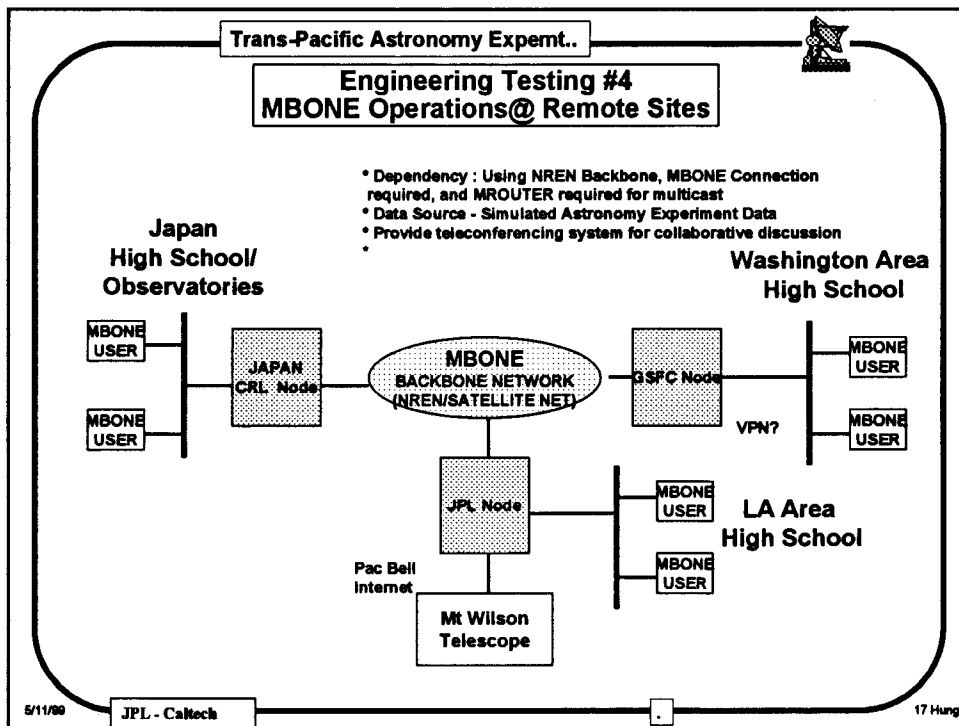
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Remote Astronomy over Trans-Pacific ATM Satellites Acknowledgement

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